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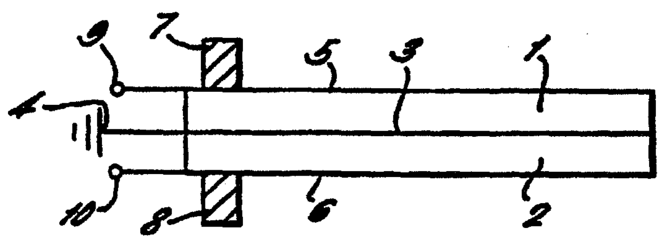
(54) **Ceramic deflection device**

(57) A monolithic ceramic device comprising an integral electrostrictive deflection element and a displacement sensor which device comprises two layers of an electrostrictive ceramic material with a central electrode sandwiched therebetween, the outer surfaces of each layer of the ceramic material having attached thereto at least one conducting electrode and means for applying a bias field across a single layer of the electrostrictive ceramic material.



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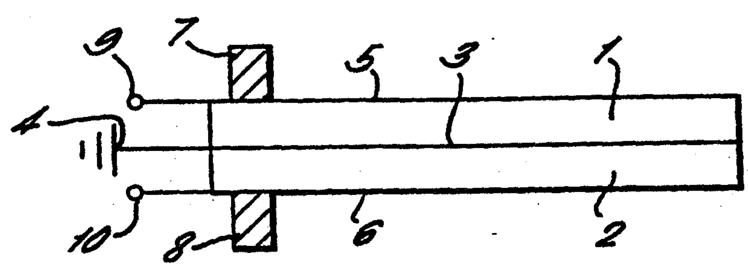

(57) Abstract

A monolithic ceramic device comprising an integral electrostrictive deflection element and a displacement sensor which device comprises two layers of an electrostrictive ceramic material with a central electrode sandwiched therebetween, the outer surfaces of each layer of the ceramic material having attached thereto at least one conducting electrode and means for applying a bias field across a single layer of the electrostrictive ceramic material.

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CERAMIC DEFLECTION DEVICE

The present invention relates to a ceramic deflection device and, in particular, to a method of producing and operating a monolithic ceramic deflection device and displacement sensor which does not employ a piezoelectric sensor.

Ceramic bending devices utilizing the converse piezoelectric effect are well known in the art. This is the phenomenon by which an applied electric field generates a proportional shape change in such materials. Devices often take the form of so-called bimorphs and multimorphs. The operating principle is identical in both cases. Alternating layers of piezoelectric ceramic are poled, usually in antiparallel directions. The application of an electric field induces a transverse compressive strain in those layers having polar directions parallel to the field, due to the piezoelectric coefficient d_{31} of the piezoelectric ceramic material. Conversely, transverse tensile strain is induced in layers poled antiparallel to the applied field. The free end of the device is deflected by an amount determined by the magnitude of the applied field, d_{31} and various geometrical factors. The displacement is reversed on reversal of the field direction. It is usual to apply the same electric field across all of the layers of the device.

EP-A-0137148 describes such a piezoelectric bimorph constructed from piezoelectric ceramic layers which are poled. This device has the advantage of a monolithic sensor enabling feedback control. The piezoelectric sensor portion of the device operates without the application of an externally applied electric bias field. The device is made to bend by

the application of an electric field to the remainder. This places a stress on the sensor portion, causing current to flow which can be related to the displacement of the element.

GB-A-2006541 discloses a piezoelectric bimorph which has a pair of oppositely polarized piezoelectric elements bonded to a common substrate. A drive circuit applies a deflection voltage to each element in the same sense as the polarization of the element and thus avoids depolarization of the elements. The device does not include a displacement sensor.

EP-A-0262637 discloses a piezoelectric bimorph device in which the piezoelectric ceramic layers are poled in the same direction and the application of an electric field across each layer causes bending. The device does not include a displacement sensor.

Similar bending devices employing the electrostrictive effect are also known. Again, this is a field-induced shape change, although the effect does not require the poled structure essential for piezoelectrics.

In one example, two ceramic layers are bonded, in such a way as to enable electrical contact, to the major surfaces of a metal shim and electrodes applied to their opposite surfaces. The application of an electric field between the metal shim and the upper external electrode causes upwards deflection. This is explained by the transverse electrostrictive coefficient, M_{12} or Q_{12}, which places the upper ceramic layer under compressive strain. The deflection obtained varies, amongst others, as a function of the square of the applied field and, therefore, reversal of the electic field direction induces identical upwards deflection.

When the electric field is applied between the metal shim and the lower electrode, downwards

deflection is produced, regardless of the field direction.

Since electrostriction is a quadratic effect, the above described device requires modification if linear, bi-directional deflection is required. This may be achieved by the application of a d.c. bias field, Vb, across each of the layers. The value of Vb is varied by equal but opposite amounts, δV, to generate the linear displacement.

The prior art ceramic bending devices suffer from certain disadvantages. Piezoelectric devices require poling, the process by which a strong d.c. bias field is applied prior to normal operation to aligh dipoles in the material. In the poled condition, there is a linear, but hysteretic, relationship between induced displacement and applied fields. Additionally, the poled structure is metastable, being randomized under the influence of time, temperature and electric field. These disadvantages of piezoelectric materials and devices apply equally to piezoelectric displacement sensors.

We have now developed an electrostrictive deflection element comprising an integral sensor and a method for the fabrication thereof.

Accordingly, the present invention provides a monolithic ceramic device comprising an integral electrostrictive deflection element and a displacement sensor which device comprises two layers of an electrostrictive ceramic material with a central electrode sandwiched therebetween, the outer surfaces of each layer of the ceramic material having attached thereto at least one conducting electrode and means for applying a bias field across a single layer of the electrostrictive ceramic material.

The central electrode of the deflection element of the present invention is generally connected to the

earth.

The electrostrictive deflection device and sensor of the present invention together form a monolithic element, i.e. the sensor is an integral part of the device rather than, for example, a bonded strain gauge or capactive displacement sensor.

The present invention also includes within its scope a method for the fabrication of a monolithic element as defined above, which method comprises forming a sandwich of a central electrode between two layers of an electrostrictive ceramic material, the outer surface of each of the layers of the ceramic material having a conducting electrode formed thereon.

The monolithic ceramic device may be formed by bonding individual ceramic plates onto a metal substrate which forms the central electrode, for example by means of an adhesive, or by depositing the electrostrictive ceramic material onto the metal substrate. The electrodes may be attached to the outer surface of each layer of the electrostrictive ceramic material by electrodeposition or other methods known in the art. Alternatively, the monolithic device may be formed by the method of tape casting the ceramic material, electroding, forming a laminate and firing the structure, in a manner similar to that used in the production of multilayer ceramic capacitors.

The present invention also includes within its scope a method of operating an electrostrictive deflection element and displacement sensor as hereinbefore defined, which method comprises applying a potential to the conducting electrode on one layer of the electrostrictive ceramic material and applying a d.c. bias voltage to the conducting electrode on the other layer of the electrostrictive ceramic material, and measuring the charge. The charge, Q, which is generated by the sensor portion of the structure may

be measured by conventional techniques. The deflection of the electrostrictive deflection element may thus be controlled by a feedback mechanism.

The present invention will be further described with reference to

Figures 1 to 4 of the accompanying drawings, in which;

Figure 1 is a schematic illustration of the device of the present invention;

Figure 2 is a schematic illustration of the device of the invention caused to deflect upwardly;

Figure 3 is a schematic illustration of the device of the invention caused to deflect downwardly; and

Figure 4 is a graph of the sensor output voltage against the applied voltage for the device as described in the Example.

Referring to the drawings, two layers of an electrostrictive ceramic material, 1 and 2 are bonded to a central electrode 3 which is connected to earth at 4. Electrodes 5 and 6, are formed on the outer surfaces of layers 1 and 2. The device is clamped in position by means of clamps 7 and 8. The connections to the electrodes 5 and 6 are shown at 9 and 10, respectively.

As shown in Figure 2, the application of a potential V to the upper electrode 5 induces an upwards deflection of the device, due to the transverse electrostrictive effect. A d.c. bias voltage, Vb, is simultaneously applied to the lower electrode 6 and causes the lower section of the device to act as a sensor, generating a charge flow which is proportional to the change in displacement. Under constant conditions, the magnitude of the current is dependent only upon the variation in deflection. This technique can be employed to control the deflection by a feedback technique (not shown).

Referring to Figure 3, the situation is reversed with the potential V being applied to the lower electrode 6 and the d.c. bias voltage, Vb, being applied to the upper electrode 5.

Without the application of the d.c. bias across the upper or lower layer, the sensor portion of the device of the invention is inoperative. This feature differentiates the present invention from those deflection devices which employ piezoeletric sensors, which operate without a d.c. bias.

The application of the d.c. bias field to the sensor portion of the device itself causes a deflection which opposes that generated by the deflecting portion. Consequently, the d.c. bias voltage may be maintained at a relatively small value, typically about 20 V, to obtain large displacements. It follows, however, that the effective stiffness of the device, which is the resistance to deflection, can be controlled by variation of the d.c. bias, a larger d.c. bias providing a greater resistance to deflection. This type of device may be used in active vibration control.

The present invention will be further described with reference to the following Example.

EXAMPLE

A device of the type as described with reference to Figure 1 of the accompanying drawings was prepared from an electrostrictive material based on lead magnesium niobium titanate, $Pb(Mg_{1/3}Nb_{2/3})O_3\text{-}PbTiO_3$.

The fired device consisted of layers of the ceramic material approximately 200 μm thick, separated by a central palladium electrode. Electrical contacts were made to the surfaces of the ceramic layers as shown in Figure 1. A d.c. bias

voltage of 15 V was applied to the ceramic layer chosen to operate as a sensor and a triangle wave drive voltage was applied to the ceramic layer chosen to operate as an actuator. Displacement of the actuator placed a stress on the sensor, causing the generation of a proportional output signal. The sensor output signal (in mV) is plotted in Figure 4 as a function of the voltage applied to the actuator. The response is electrostrictive in nature, as expected for the motion of the actuator. The offset in the response is a natural consequence of the application of the d.c. bias to the sensor portion and can be removed by the application of an equal d.c. bias offset to the actuator portion.

CLAIMS:

1. A monolithic ceramic device comprising an integral electrostrictive deflection element and a displacement sensor which device comprises two layers of an electrostrictive ceramic material with a central electrode sandwiched therebetween, the outer surfaces of each layer of the ceramic material having attached thereto at least one conducting electrode and means for applying a bias field across a single layer of the electrostrictive ceramic material.

2. A deflection element as claimed in claim 1 wherein the central electrode is connected to earth.

3. A method for the fabrication of a monolithic ceramic device as claimed in claim 1, which method comprises forming a sandwich of a central electrode between two layers of an electrostrictive ceramic material, the outer surface of each of the layers of the ceramic material having a conducting electrode formed thereon.

4. A method as claimed in claim 3 wherein individual ceramic plates are bonded to a metal substrate which forms the central electrode.

5. A method as claimed in claim 3 wherein the ceramic layers are formed by depositing the electrostrictive ceramic material onto the metal substrate.

6. A method as claimed in claim 3 wherein the monolithic device is formed by tape casting the ceramic material, electroding, forming a laminate and firing the structure.

7. A method of operating an electrostrictive deflection element and displacement sensor as claimed in claim 1, which method comprises applying a potential to the conducting electrode on one layer of the electrostrictive ceramic material and applying a d.c. bias voltage to the conducting electrode on the other layer of the electrostrictive ceramic material, and measuring the charge.

8. A method as claimed in claim 7 wherein the deflection of the electrostrictive deflection element is controlled by a feedback mechanism.

9. A method of controlling the resistance to deflection of an electrostrictive deflection element and sensing device as claimed in claim 1, which method comprises varying the d.c. bias voltage applied to the conducting electrode on one layer of the electrostrictive ceramic material, whilst applying a potential to the conducting electrode on the other layer of the electrostrictive ceramic material.

FIG. 1.

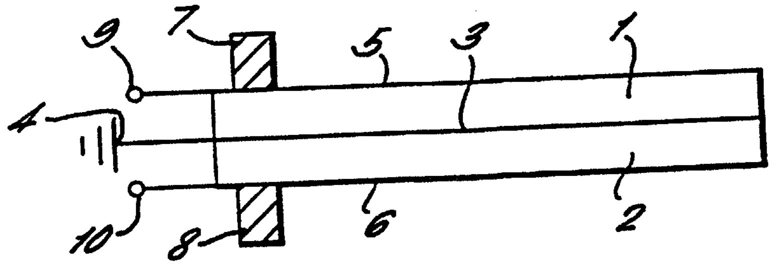


FIG. 2.

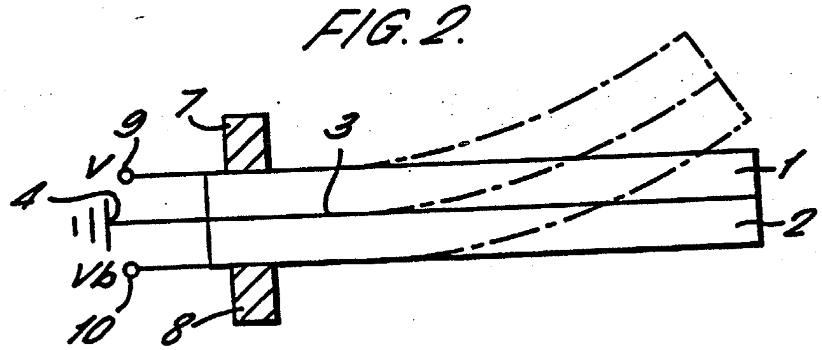


FIG. 3.

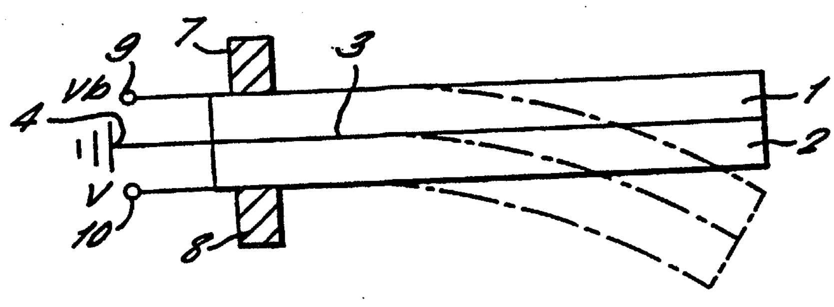
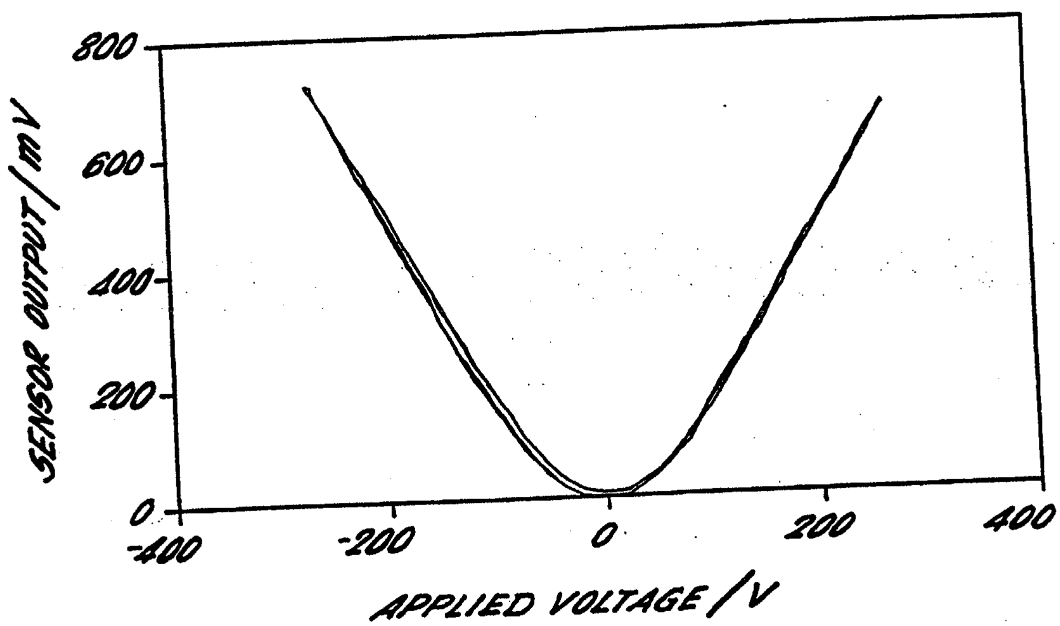


FIG. 4.


800
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SENSOR OUTPUT / mV
-400
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APPLIED VOLTAGE / V

INTERNATIONAL SEARCH REPORT

International Application No
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A. CLASSIFICATION OF SUBJECT MATTER
IPC 5 H01L41/09

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 5 H01L

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C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US,A,4 594 526 (NEC CORPORATION) 10 June 1986 see abstract; figure 2	1
A	EP,A,0 137 148 (IBM) 17 April 1985 cited in the application see abstract; figure 3	1

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INTERNATIONAL SEARCH REPORT

Information on patent family members

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